

**CHEMISTRY
HIGHER LEVEL
PAPER 3**

Candidate number

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Wednesday 19 May 2004 (morning)

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your candidate number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

Option B – Medicines and Drugs

B1. The structures of some analgesics are shown in Table 21 of the Data Booklet. Refer to this table when answering part (b) of this question.

- (a) Explain the difference in the method of action of mild analgesics and strong analgesics. [2]

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- (b) State the name of the nitrogen-containing functional group in each of the following molecules. [2]

Paracetamol

Heroin

B2. Penicillins are molecules that can kill harmful micro-organisms. Their general structure is shown in Table 21 of the Data Booklet.

- (a) State the type of micro-organism killed by penicillins and explain how they do this. [4]

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- (b) Explain the effect of overprescription of penicillins. [3]

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- B3.** Describe the differences between bacteria and viruses, by referring to their structures and the way they multiply. [4]

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- B4. (a)** Outline the difference between a local anesthetic and a general anesthetic. [2]

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- (b)** The choice of a general anesthetic in surgery depends on several features, such as potency, flammability and environmental effects. Give the formula, and discuss the advantages and disadvantages, of each of the anesthetics trichloromethane and cyclopropane. [6]

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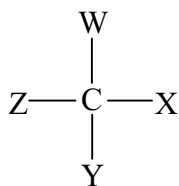
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B5. Some drug molecules contain a structure that can be represented as follows.



(a) Draw the **two** enantiomeric forms of this structure.

[1]

(b) Explain the term *racemic mixture*.

[1]

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Option C – Human Biochemistry

- C1.** (a) The structures of three important vitamins are shown in Table 22 of the Data Booklet. State the name of each one and deduce whether each is water-soluble or fat-soluble, explaining your choices by reference to their structures. [5]

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- (b) Fresh fruits and vegetables are good sources of vitamin C.

- (i) Identify **one** major function of vitamin C in the human body. [1]

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- (ii) Explain why some meals made from these foods may contain little vitamin C. [2]

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C2. The structures of two sex hormones, progesterone and testosterone, are shown in Table 22 of the Data Booklet.

- (a) State the names of **two** functional groups that are present in **both** hormones. [2]

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- (b) Identify which of the two hormones is the female sex hormone and where in the human body it is produced. [2]

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- (c) Outline the mode of action of oral contraceptives. [3]

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C3. Enzymes are important molecules in the chemistry of living organisms.

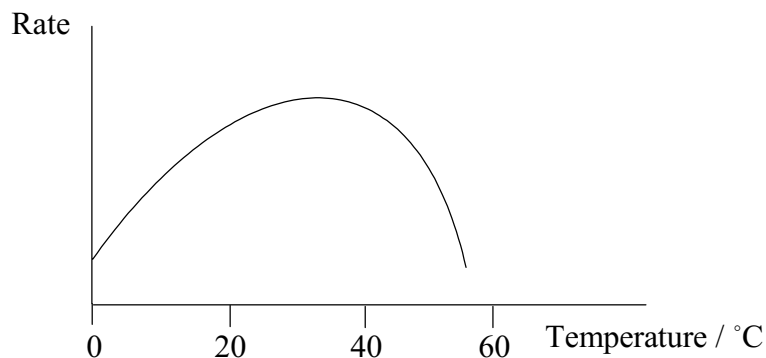
- (a) State what type of molecule an enzyme is and state the function of enzymes.

[2]

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- (b) Explain the shape of the following graph for a reaction involving an enzyme.

[4]



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- C4.** The roles of metal ions in the body depend on their chemical properties. The charges and radii of three metal ions are given in the following table.

Metal ion	Charge	Ionic radius / pm
X	+2	65
Y	+1	68
Z	+1	98

- (a) Identify the ion most likely to produce rapid changes such as those involved in nerve action, and explain your choice. [2]

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- (b) Identify the ion most likely to be part of a structural unit, and explain your choice. [2]

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Option D – Environmental Chemistry

D1. Nitrates in drinking water can cause health problems.

- (a) Identify **one** source of nitrates in drinking water and explain why nitrates can be a health problem. [2]

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- (b) Identify the stage of waste water treatment in which nitrates can be removed and state **one** method for nitrate removal. [2]

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D2. Explain why ozone is used in water treatment and state **two** advantages of using ozone rather than chlorine. [3]

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D3. The term *greenhouse effect* is used to describe a natural process for keeping the average temperature of the Earth’s surface nearly constant.

- (a) Describe the greenhouse effect in terms of radiations of different wavelengths. [4]

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- (b) Water vapour acts as a greenhouse gas. State the main natural and man-made sources of water vapour in the atmosphere. [2]

Natural source

Man-made source

- (c) Two students disagreed about whether carbon dioxide or methane was more important as a greenhouse gas.

- (i) State **one** reason why carbon dioxide could be considered more important than methane as a greenhouse gas. [1]

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- (ii) State **one** reason why methane could be considered more important than carbon dioxide as a greenhouse gas. [1]

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(This question continues on the following page)

(Question D3 continued)

(d) Discuss the effects of global warming on the Earth.

[4]

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D4. Photochemical smog is an increasing problem. Outline the causes and effects of photochemical smog by referring to **each** of the following:

- its origin
- the weather conditions needed
- the chemical compounds present
- the effects on human health.

[6]

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Option E – Chemical Industries

E1. A major product of oil refining is fuel for automobiles. Two processes used in the refinery are sulfur removal and reforming.

- (a) (i) Explain why sulfur is removed from oil. [2]

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- (ii) Hydrogen sulfide can be reacted with sulfur dioxide to produce one of the raw materials for sulfuric acid manufacture. Deduce the equation for this reaction. [2]

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- (b) The process of reforming converts straight-chain alkanes into more useful hydrocarbons. For example, hexane, $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$, can be converted into the compounds $(\text{CH}_3\text{CH}_2)_2\text{CHCH}_3$ and C_6H_6 .

- (i) For each of these conversions, state the type of reforming process and the name of the compound formed. [4]

$(\text{CH}_3\text{CH}_2)_2\text{CHCH}_3$

 C_6H_6

- (ii) The formation of C_6H_6 from hexane results in another product. Identify this product and state **one** industrial use for it. [2]

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E2. Aluminium is produced on a large scale by the electrolysis of alumina.

(a) Give the formula of alumina.

[1]

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(b) Explain why cryolite is used in the process.

[2]

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(c) Write an equation to show what happens to each of the following ions during electrolysis

[2]

Al^{3+}

O^{2-}

E3. Pure silicon is a semiconductor. Explain how the addition of small amounts of gallium or arsenic changes the conductivity of silicon.

[6]

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- E4.** The species $\text{CH}_3\text{CH}_2\text{CH}_2^+$ and $\text{CH}_3\text{CH}_2\text{CH}_2^\bullet$ are produced in cracking processes in the organic chemicals industry. Compare the mechanisms of the reactions in which these species are produced by completing the following table.

Species	Type of cracking	Type of bond fission
$\text{CH}_3\text{CH}_2\text{CH}_2^+$		
$\text{CH}_3\text{CH}_2\text{CH}_2^\bullet$		

[4]

Option F – Fuels and Energy

F1. State **two** advantages of converting coal to a liquid fuel. [2]

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F2. One of the compounds present in gasoline is heptane, C_7H_{16} . Heptane has an octane number of 0.

(a) State the name of the problem that occurs when heptane is used as the fuel in an automobile engine. [1]

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(b) State the name of the alkane that has an octane number of 100. [2]

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(c) Outline the structural difference between heptane and the alkane in (b). [1]

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(d) Suggest **one** type of substance that could be added to heptane to increase the octane number of the fuel. [1]

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(This question continues on the following page)

(Question F2 continued)

- (e) A sample of heptane was burned in a calorimeter. Calculate the molar enthalpy of combustion of heptane using the following data.

Mass of heptane burned = 2.00 g

Mass of water in calorimeter = 250 g

Temperature change of water = 52.7 °C

[5]

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- F3.** Discuss the similarities and differences between *nuclear fission* and *nuclear fusion*, in terms of the masses and energies of the particles involved.

[3]

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- F4.** Surplus energy from fossil fuel or nuclear power stations may be stored in hydroelectric (pumped storage) schemes or in the production of hydrogen. Discuss the advantages and disadvantages of each method of storage. [6]

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- F5.** The radioisotope Ra-225 is a beta-emitter with a half-life of 14.8 days.

- (a) Write the equation for the radioactive decay of Ra-225. [1]

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- (b) Calculate the time for the activity of a sample of Ra-225 to decrease to 10 % of its original value. [3]

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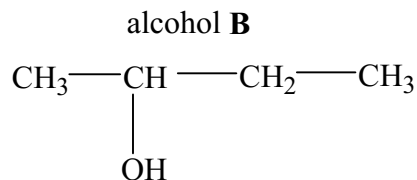
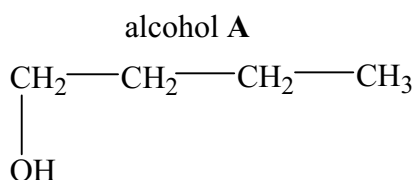
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Option G – Modern Analytical Chemistry

G1. There are four isomeric alcohols with the molecular formula $C_4H_{10}O$. They can be distinguished using a variety of analytical techniques.

- (a) The structures of two of the alcohols (**A** and **B**) are shown below. Draw a structure for each of the other two alcohols (**C** and **D**). [2]



alcohol **C**

alcohol **D**

- (b) Explain why the four compounds could not easily be distinguished by looking at their infrared spectra. [1]

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- (c) The ^1H NMR spectra of **A** and **B** both show the same number of peaks, but with a different ratio of areas under the peaks.

- (i) State what can be deduced from the number of peaks in an ^1H NMR spectrum. [1]

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- (ii) Deduce the number of peaks in the ^1H NMR spectra of **A** and **B**. [1]

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- (iii) Determine the ratio of areas under the peaks for **A** and **B**. [2]

A

B

(This question continues on the following page)

(Question G1 continued)

- (d) One of the alcohols, **C** or **D**, has a high resolution ^1H NMR spectrum that shows only peaks that are singlets. Identify which alcohol it is, and explain why there is no splitting of the peaks. [2]

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- (e) Explain the following features of the mass spectra of **A** and **B**.

- (i) Both spectra show a peak at $m/z = 74$. [1]

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- (ii) One spectrum shows a prominent peak at $m/z = 45$ but the other shows a prominent peak at $m/z = 31$. [2]

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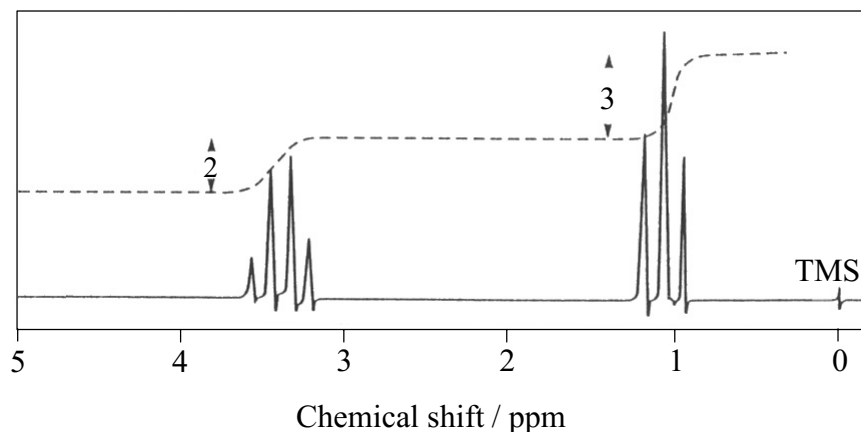
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(Question G1 continued)

- (f) Another compound, **E**, with molecular formula $C_4H_{10}O$, has an 1H NMR spectrum as follows:



- (i) Explain the splitting patterns in the spectrum.

[3]

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- (ii) Compound **E** has an absorption in its infrared spectrum close to 1150 cm^{-1} . Deduce which bond in **E** is responsible for this and use the information from both spectra to deduce the structure of **E**.

[2]

Bond in **E**

Structure of **E**

- G2.** (a) All chromatographic techniques involve the phenomena of adsorption or partition. They all use a stationary phase and a mobile phase, but these phases can include solids, liquids or gases. Complete the following table to show which states of matter are used in the two phenomena.

	Stationary phase	Mobile phase
Adsorption		
Partition		

[3]

- (b) Explain the term R_f value used in some chromatographic techniques.

[1]

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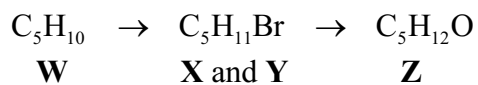
- (c) Outline how the technique of column chromatography could be used to separate a mixture of two coloured substances in solution.

[4]

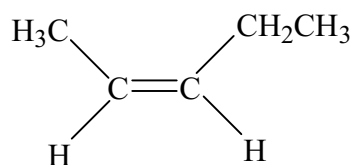
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Option H – Further Organic Chemistry

H1. This question is based on the following reaction scheme.



(a) **W** has the structure



(i) Give the structure of the geometrical isomer of **W**. [1]

(ii) Explain why **W** has a geometrical isomer. [2]

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(iii) State the full name of **W**. [2]

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(This question continues on the following page)

(Question H1 continued)

- (b) (i) State the name of the reaction mechanism by which **W** is converted to **X** and **Y**. [1]

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- (ii) The product **Y** can exist as optical isomers. Deduce the structure of **Y** and explain why it shows optical isomerism. [2]

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- (iii) Write equations (using “curly arrows” to represent the movement of electron pairs) to show the mechanism of the reaction in which **X** is formed. [4]

- (iv) Markovnikov’s rule is sometimes useful in predicting the major product in this type of reaction. Explain why this rule cannot be used to predict whether **X** or **Y** would be the major product. [2]

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(This question continues on the following page)

(Question H1 continued)

(c) The conversion of **X** to **Z** involves nucleophilic substitution by an S_N1 mechanism.

(i) Identify the species responsible for the nucleophilic attack. [1]

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(ii) State and explain how the rate of the S_N1 reaction for each of the following, using the same nucleophile as in (c)(i), compares with that of **X**. [6]

(CH₃)₃CBr

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C₆H₅Br

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H2. The pK_b values of some amines are shown in Table 16 of the Data Booklet. Write an equation for the reaction of ethylamine with water. State and explain how the basicity of ethylamine compares to that of ammonia. [4]

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